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Biotechnology-Artificial Intelligence Nexus: A Mini Review of Advanced Applications, Benefits, and Challenges in the Healthcare Domain

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ABSTRACT

The recent advancements in biotechnology and Artificial Intelligence (AI) have brought about an industry-transforming convergence with a huge potential to disrupt the healthcare sector. This review paper presents recent case studies on applications, benefits, and challenges in the healthcare industry by looking at the Biotechnology-AI Nexus. This article aims to create some background for further research, supplying information on the contemporary state of AI and biotechnology. Examples of areas covered in the study include drug development, genetics, proteomics, personalized medicine, and medical imaging. In addition, the latest breakthroughs and treatment techniques emerged from the fusion of AI with biotechnological methods such as CRISPR-Cas9 and gene-editing tools. The biotechnology artificial intelligence nexus has several applications. AI-enabled biotechnological breakthroughs may optimize workflow, make healthcare systems more efficient, and save costs in places that are not most needed. Furthermore, AI-powered analytics may illuminate complicated biological processes, creating data-centric choices that increase accuracy and personalization in healthcare. On the other hand, some impediments must be addressed before the Biotechnology-AI Nexus's actualization. Data privacy and security, ethical considerations, regulatory compliance, and cross-cutting teamwork are some of the issues that should be addressed. The possibility for AI and automation to disrupt the employment market also raises concerns regarding the displacement of workers and the need for re-skilling and up-skilling programs.

Keywords: Biotechnology; Artificial intelligence; Nexus; Health; Diagnosis; Biological; Drug; Cancer; Machine learning; Advancements.

1. Introduction

The steady rise of technological progress has affected the position of scientific achievements and initiatives and the availability of previously unexplored research fields (Gorjian et al., 2021). Integrating AI with biotechnology is a relatively new development with revolutionary potential in healthcare and this happens because both artificial intelligence and biotechnology are growing and developing rapidly as separate academic disciplines. There is a growing demand for novel solutions to complicated and varied biological problems. AI technology allows for a deeper understanding, modeling, and manipulation of biological processes due to merging these two fields (C. Chen et al., 2022). The healthcare industry benefits significantly from the combination of biotechnology and AI. AI's powerful computational skills are used in the medical and scientific communities to develop cutting-edge diagnostic tools, individualized treatment regimens, and streamlined drug development processes. It is possible to analyze patient data, spot patterns, and predict the results of a disease using AI-based techniques, allowing for more prompt treatment and tailored strategies considering each patient's unique circumstances. By rapidly screening new medication candidates and forecasting their efficacy, artificial intelligence systems save time and money throughout the drug discovery process (Moor et al., 2023).

Combining AI with biotech allows for the creation more efficient and cutting-edge methods for bioprocessing. Using machine learning algorithms in bioprocessing enables real-time monitoring and adjustment of variables, which in turn leads to cost savings, higher product quality, and more efficient use of resources. Artificial intelligence (AI)-based systems can also model and predict optimal bioprocessing conditions, which helps

researchers develop new, applicable methods for producing bio-derived products. Advances in machine learning's biotech applications can be attributed to merging of the two fields of study (Velidandi et al., 2023).

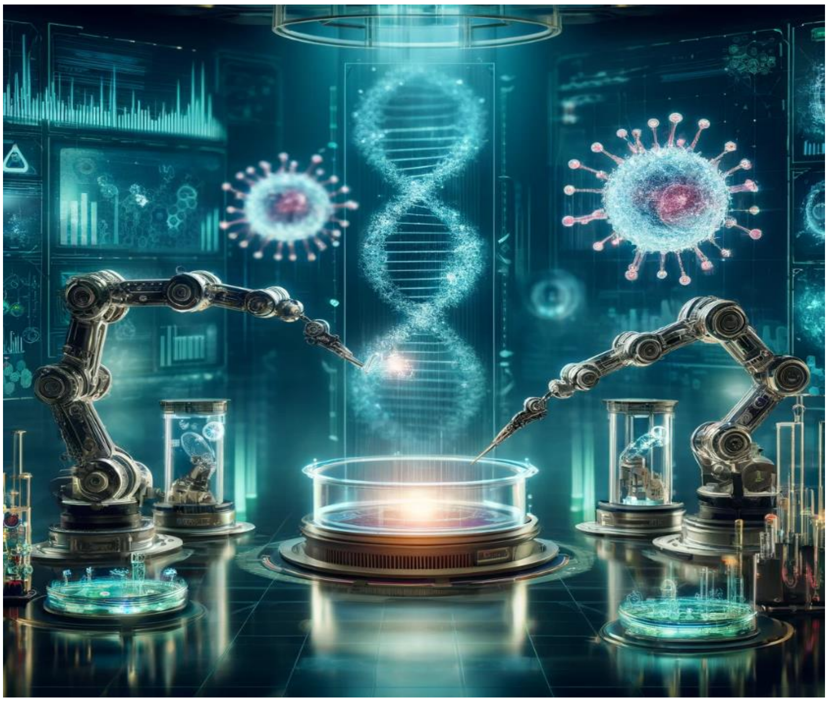

Figure 1. Attractive image of AI and Biotechnology integration (OpenAI. (2024). ChatGPT (4) [Large language model]. https://chat.openai.com)

By automating data processing and interpretation, AI-powered systems have sped up scientific discovery and improved our understanding of complex biological systems. Novel computer models are being created in this study to anticipate biological processes, including protein folding and gene expression, and it also provides the feasibility of using gene-editing tools like CRISPR-Cas9 to regulate and control biological systems in novel ways. Because of its immense potential for innovation and growth, the intersection of biotechnology and AI is attracting the attention of researchers and investors worldwide (Truong & Papagiannidis, 2022). Numerous universities, think tanks and private businesses are actively investigating this multidisciplinary area because of its potential impact on healthcare worldwide (Rodrigues, 2020). This review "Biotechnology-Artificial Intelligence Nexus: A Review of Advanced Applications, Benefits, and Challenges in the Healthcare Domain" is an in-depth look at the exciting and rapidly growing field in which biotechnology and AI meet. This integration can revolutionize how healthcare and biotechnology professionals understand and employ biological systems.

1.1. Study Objectives

(i) To educate the readers about AI.

(ii) To educate the readers about convergence between biotechnology and AI.

(iii) To elaborate the role of AI in healthcare domain.

(iv) To discuss the successful applications of AI in healthcare system.

(v) To discuss the benefits and challenges in AI-Biotech nexus.

2. Biotechnology & Artificial Intelligence: An Overview

2.1. Biotechnology

Biological processes, animals, or systems are used to power the creation of cutting-edge technologies in the highly multidisciplinary subject of biotechnology. In order to solve problems in fields as diverse as human health, agriculture, and the environment, biotechnologists commonly resort to tinkering with DNA, proteins, and cells from living things (Lysunets). Biotechnology has several uses, but one of the most visible is in the medical industry. Scientists have fabricated recombinant DNA molecules using genetic modification techniques to create life-saving drugs like insulin and human growth hormone. Gene therapy has emerged as a potentially effective method for treating genetic illnesses by removing, altering, or adding healthy copies of genes (Prado, Acosta-Acero, & Maldonado, 2020). The agriculture industry has substantially changed thanks to biotechnology in crop productivity and protection (Hesham et al., 2021). Genetically modified organisms (GMOs) are organisms with DNA that have been altered so that it is more resilient to a variety of threats, including pests, diseases, and environmental stresses like drought. As a result, the use of potentially dangerous chemical pesticides has decreased while agricultural output has increased and biotechnology has also aided the creation of nutrient-dense crops, increased food availability and improved health outcomes. Recent environmental biotechnology developments have been auspicious. This field of study emphasizes using organisms or parts of organisms to address environmental issues such as waste management, pollution, and resource conservation. Bioremediation aims to restore ecological balance by using microorganisms to break down harmful chemicals and pollutants (Arora, Kumar, Ogita, & Yau, 2022). Increased human well-being and remarkable ecological stability are benefits of biotechnology industry advancements.

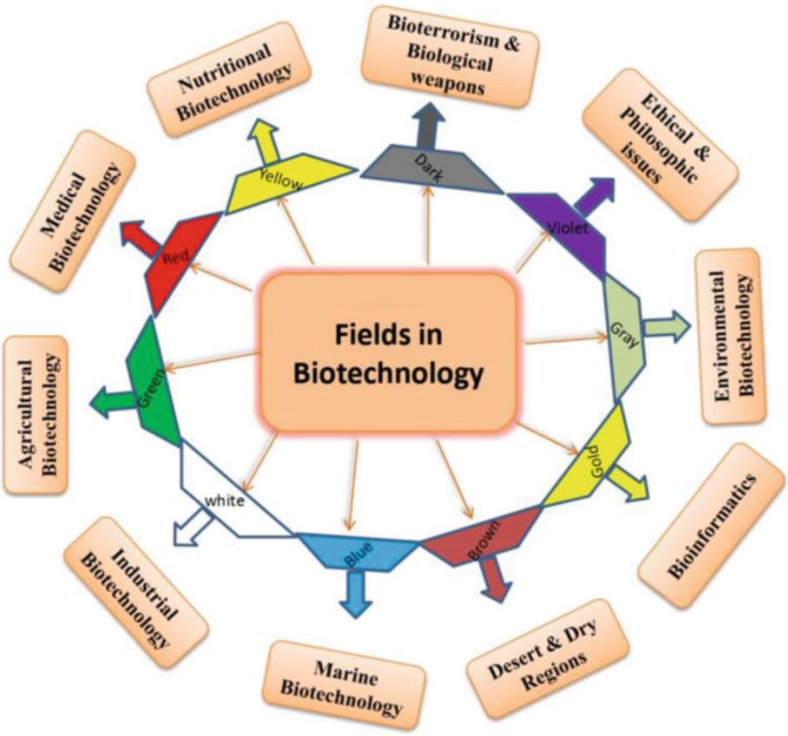

Figure 2. Classification of Biotechnology (Modified after (Padhy, Mahapatra, Saraswat, & Song, 2020))

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2.2. Artificial Intelligence (AI)

Artificial intelligence (AI) is an area of computer science that aspires to create machines with human-level intelligence. Building algorithms and models that mimic human intelligence so that computers can learn from data, adapt to new situations, and carry out complex jobs is what this refers to (Abonamah, Tariq, & Shilbayeh, 2021). Natural language processing (NLP), a branch of AI, is increasingly considered essential. This technical progress benefits from voice assistants, chatbots, and machine translation apps since it allows robots to understand, interpret, and produce human language. The advancement of Natural Language Processing (NLP) has dramatically improved the efficiency with which people and machines can exchange information (Kuddus, 2022). Computer vision, the ability of computers to process and make sense of visual input from the outside world, is another important use. Many industries have found uses for this technology, from medical imaging to driverless cars. Diagnostic technologies based on AI can examine medical pictures with pinpoint accuracy, helping doctors spot abnormalities and illnesses. As a result, medical professionals can make better judgments for their patients (Vijaya, 2022). Artificial intelligence (AI) is essential in robotics because it allows robots to navigate and interact with their environment without human intervention. As a result of this occurrence, complex robotic systems have emerged that can carry out a wide range of tasks, from product assembly to surgical aid to the exploration of dangerous environments like the depths of the ocean or outer space (Wan, Gu, & Ni, 2020). The versatility and promise of Artificial Intelligence (AI) have been demonstrated by its use in a wide range of domains, from banking and marketing to education(Kaswan, Dhatterwal, Kumar, & Lal, 2023).

2.3. Convergence of the Biotechnology & Artificial Intelligence

A new age of creativity and discovery has begun with the merging of biotechnology and artificial intelligence. Researchers can learn more and provide better answers to complex biological problems if they use AI and biotechnological approaches together. Genomics is a prominent example of this convergence since it uses AI methods like machine learning and deep learning to evaluate large volumes of genetic data. Understanding how genes interact and contribute to different traits and illnesses allows scientists to uncover patterns and links in DNA sequences. Because of this, tailored treatments and targeted therapeutics may be developed more quickly thanks to AI-powered genomics research (Johnson et al., 2021). One such place where the two disciplines meet is in drug discovery. Artificial intelligence systems can examine enormous databases of chemical substances and biological targets far more rapidly and correctly than human experts. Applying AI to drug development helps researchers save time and money while raising the chance of finding successful medicines for various ailments (Hassanzadeh, Atyabi, & Dinarvand, 2019). Synthetic biology has also advanced due to the union of AI and biotechnology, allowing scientists to create innovative biological systems tailored to perform specific tasks. Artificial intelligence may assist with the design process by foreseeing how alterations to DNA would influence the performance of organisms or their parts (Kim, 2020). This paves the way for creating biofuels, biodegradable polymers, and tailored medicine delivery systems that are more efficient and accurate than their predecessors. Finally, combining biotechnology with AI can potentially revolutionize many fields, from medicine and agriculture to ecology and energy. By using AI to decipher complex biological data, scientists may shed light on major global issues and develop novel approaches to addressing them (Holzinger, Keiblinger, Holub, Zatloukal, & Müller, 2023).

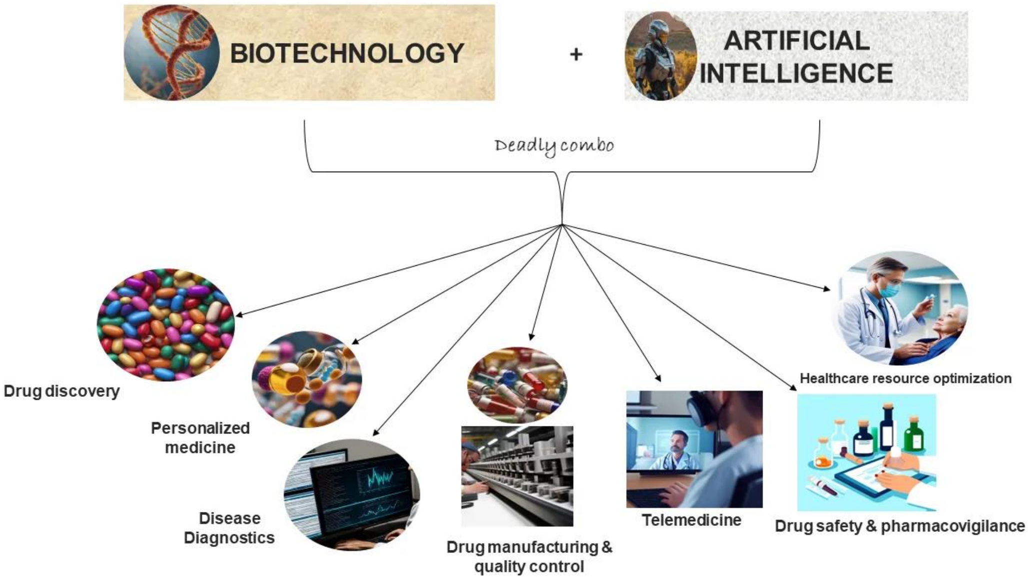

Figure 3. Image illustrates the different areas of biotechnology in which AI can be applied to improve their functioning (Kashkha, 2023)

3. Applications and Case Studies of Artificial Intelligence & Biotechnology in Healthcare Domain

More accurate diagnoses of diseases and individualized treatment plans are now possible because of advancements in biotechnology and artificial intelligence (AI). Significant progress has been made in many areas of medicine due to merging these two disciplines, including imaging, genetics, drug development, and telemedicine. X-rays, MRI scans, and CT scans are just some of the medical pictures that may be analyzed by AI-powered systems used in illness diagnosis. For instance, cancer, Alzheimer's, and heart disease may all be detected earlier using deep learning algorithms trained to spot patterns in medical pictures (Singh, Singh, Singh, & Singh, 2021).

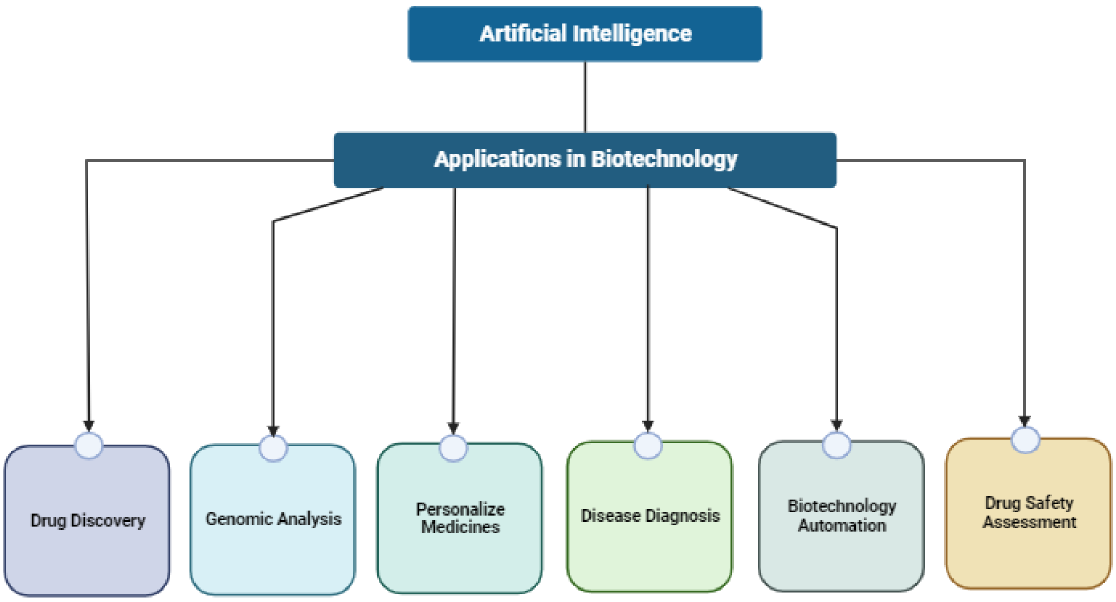

Figure 4. Applications used in Bioecology by using Artificial Intelligence

Molecular diagnostic technologies like polymerase chain reaction (PCR) and next-generation sequencing (NGS) are only possible due to biotechnology's contribution to medicine. Identifying a disease's unique genetic

fingerprint, infectious agent, or biomarker paves the way for preventative measures and individualized care. Artificial intelligence (AI) algorithms are used in the healthcare industry to sift through mountains of patient and genomic data in search of individualized treatments, allowing doctors to personalize therapy for each patient, which boosts treatment success and reduces adverse effects (Waden, 2022).

3.1. Case Studies of Successful Applications

3.1.1. AI-Based Diagnoses for Diabetic Retinopathy

Retinal microangiopathy, or diabetic retinopathy, is a frequent consequence of diabetes that causes gradual vision loss and, in extreme cases, blindness. One-third of persons with diabetes are expected to have diabetic retinopathy, which is a primary cause of blindness globally, according to the World Health Organization (Kropp et al., 2023). Preventing blindness and improving patient outcomes requires prompt diagnosis and treatment. Artificial intelligence (AI) has become an invaluable resource for the early diagnosis and management of diabetic retinopathy, with companies like DeepMind, a Google subsidiary, developing AI-powered systems that can analyze retinal images and make diagnoses on par with human specialists. There are several benefits of using AI to diagnose diabetic retinopathy over more conventional approaches. Screening programs can save time and resources by the accuracy and speed with which AI-based systems can scan vast numbers of retinal pictures. Diabetic retinopathy screening and diagnosis may be expanded to underserved and rural regions using AI-powered solutions.

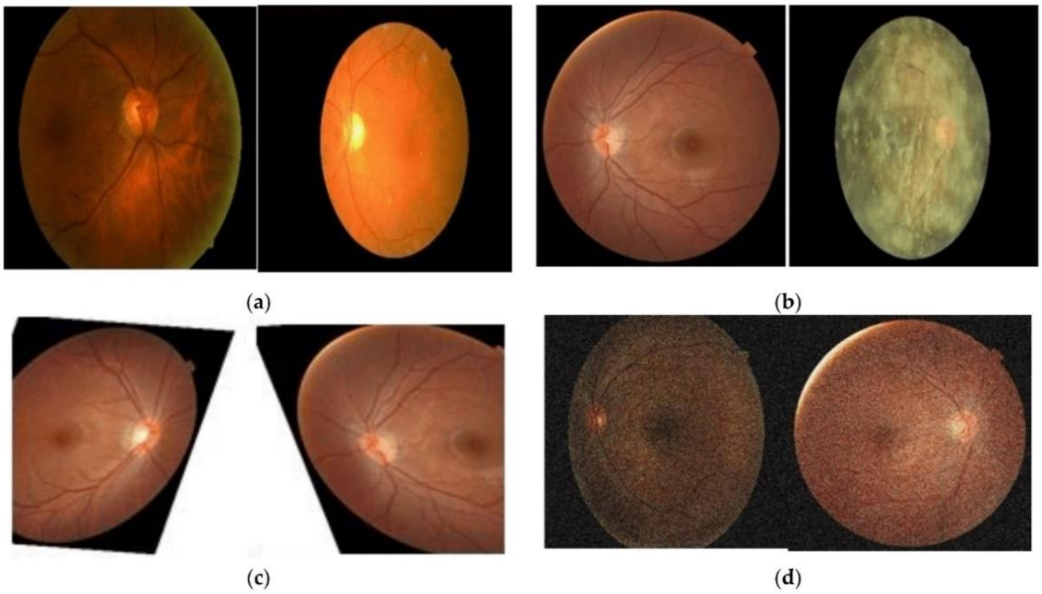

Figure 5. Some images from the training set and the effect of preprocessing, which allows us to increase the size of the input dataset: (a) Images with symptoms; (b) Asymptomatic images; (c) Pictures with left and right rotation; (d) Images with noise (This image is taken from reference (Asia et al., 2022))

Deep learning methods, a subset of machine learning techniques that involves training artificial neural networks to spot patterns in data, form the basis of DeepMind's AI system for diagnosing diabetic retinopathy (Raman et al., 2019). To "learn" the traits associated with diabetic retinopathy, an AI system is trained on thousands of retinal pictures annotated by human specialists. Once taught, the system can quickly and accurately diagnose fresh retinal

pictures. Researchers from DeepMind and Moorfields Eye Hospital released a groundbreaking report in JAMA showcasing the efficacy of their AI system in diagnosing diabetic retinopathy. On a dataset of 128,175 retinal pictures, the algorithm identified referable diabetic retinopathy with an accuracy of 94.5%, which is on par with the performance of human experts (Gulshan et al., 2016). The AI system could deliver a diagnosis in seconds, significantly quicker than human specialists. Diabetic retinopathy identification is only one area where AI-based diagnostics might be helpful. Artificial intelligence technologies can also aid in tracking a patient's condition over time to assess how well their treatment works. More effective and individualized treatment for patients with diabetic retinopathy is possible because of the integration of AI into electronic health records and telemedicine systems, which allows for better communication between healthcare professionals (Ting et al., 2019).

3.1.2. IBM Watson for Oncology

IBM Watson for Oncology is an AI platform created to help with this problem by evaluating large volumes of medical data and recommending the best cancer therapies to clinicians. Medical records, scholarly articles, and clinical trial results are just some data types that IBM Watson for Oncology analyzes using NLP and ML algorithms. Watson can develop individualized treatment plans for each patient by including criteria like tumor kind, stage, and molecular features. IBM Watson for Oncology's speed in processing and synthesizing complicated information is a significant benefit since it lessens the burden on busy doctors to perform manual data reviews and interpretations. This can be especially helpful in the field of cancer, where prompt and accurate treatment decisions are essential for the best possible patient results. Watson's capacity to analyze massive amounts of data and spot trends also means it can point doctors toward treatments they had not considered trying before (Ahmed, Toor, O'Neil, & Friedland, 2017).

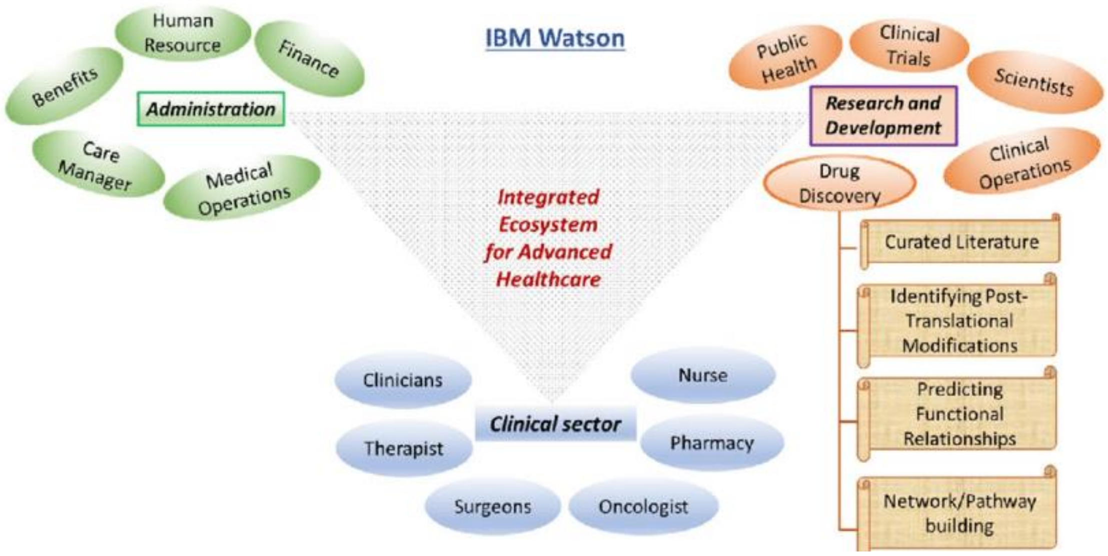

Figure 6. Diagrammatic representation of different functional modules in the big data healthcare package of IBM Watson (This image is taken from reference (Dash, Shakyawar, Sharma, & Kaushik, 2019))

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This can be especially helpful in the field of cancer, where prompt and accurate treatment decisions are essential for the best possible patient results. Watson's capacity to analyze massive amounts of data and spot trends also means it can point doctors toward treatments they had not considered trying before. IBM Watson for Oncology has shown encouraging outcomes in clinical decision-making evaluations across many trials. The treatment suggestions made by Watson and those of a multidisciplinary tumor board were shown to have a high degree of agreement in a study done at the Manipal Comprehensive Cancer Center in India. Watson's recommendations were congruent with expert judgments in 93% of cases, indicating that the AI platform may successfully enhance clinical decision-making in cancer (Somashekhar et al., 2018). As patient information is so sensitive, protecting it while the AI platform processes it is paramount. Watson's suggestions may affect patient outcomes such as overall survival, quality of life, and treatment-related side effects, but this will require more study. To conclude, continuing cooperation between AI engineers, healthcare professionals, and patients is necessary to ensure that IBM Watson for Oncology is user-friendly, accessible, and successful in enhancing cancer treatment as it is implemented into routine clinical procedures (Rebelo, Sanders, Li, & Chow, 2022).

3.1.3. Zipline's Drone Delivery for Medical Supplies

Zipline is an AI-powered drone delivery service that transports lifesaving medications and medical supplies to outlying clinics in Rwanda and Ghana. The timely delivery of these supplies has increased access to healthcare and saved lives in these neglected areas, all thanks to Zipline's drones (Yathiraju & Mohapatra, 2023). In order to ensure that even the most inaccessible places have access to lifesaving medical supplies, healthcare logistics plays a crucial role in modern healthcare delivery systems. In areas with inadequate infrastructure and challenging terrain, conventional modes of transportation, such as trucks and motorbikes, can be sluggish, unreliable, and expensive (Schaeffer & Olson, 2019). Zipline's drone delivery service overcomes these constraints by utilizing cutting-edge technology and novel delivery techniques to provide patients with their medication on time. Zipline's AI-enabled drones can automatically optimize flight courses, avoid obstructions, and adapt to changing weather conditions. Drones' built-in sensors and GPS systems precisely pinpoint delivery sites, guaranteeing the safe and secure delivery of essential medical supplies. After dropping off their cargo, the drones return to the base to recharge and restock. Rwanda and Ghana have significantly benefited from Zipline's drone delivery service, which has increased patients' access to care and improved their health results. Zipline has set up a countrywide drone delivery network in Rwanda, giving fast access to blood supplies for transfusions and emergency treatment to more than 25 hospitals and health institutions (Shava, 2022).

Over 15,000 units of blood have been transported by Zipline since its introduction in 2016, preventing thousands of unnecessary transfusions and saving countless lives. Zipline runs four distribution sites in Ghana, which supply over 2,000 healthcare establishments (Tarr et al., 2021). The company's AI-powered drones transport medical supplies to clinics and hospitals, such as vaccinations, drugs and diagnostic kits. As a result, diseases like malaria and TB are being diagnosed and treated faster than before, and vaccination rates have increased. The widespread interest and imitation of Zipline's drone delivery service attest to its success. In the United States, companies like Wing and UPS have been permitted to test out drone delivery of medical supplies. In Malawi, UNICEF has collaborated with local authorities to set up a drone corridor for transporting vaccines and other health

commodities. Despite the potential of drone delivery for healthcare logistics, various obstacles must be overcome to make the projects sustainable and scalable (Haidari et al., 2016). Safe integration of drones into national aviation systems requires the creation of regulatory frameworks and the investment in infrastructure to enable drone operations and maintenance. Trust and acceptability for drone delivery services can only be established by concerted efforts by governments, business sector partners, and local communities to ensure that the advantages of this revolutionary technology are distributed fairly and ethically (Lockhart et al., 2021).

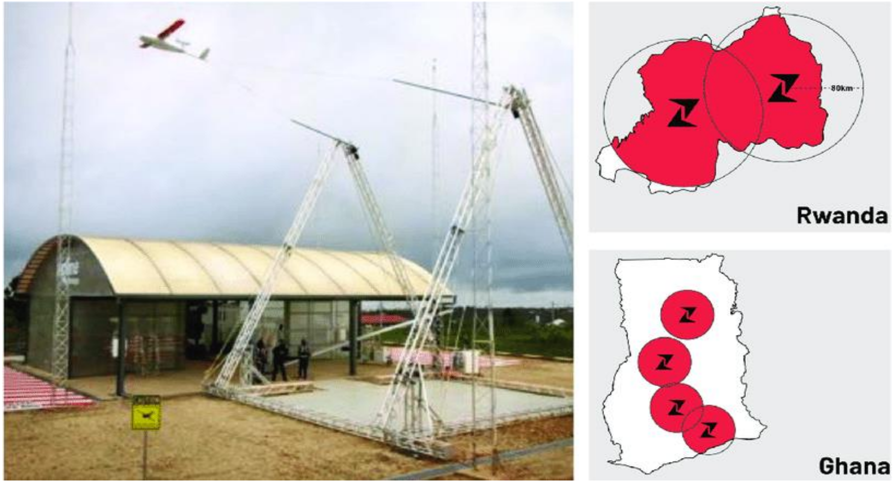

Figure 7. Left- Centre for drone launches in western Rwanda. Right- Map of the Rwandan and Ghanaian zipline centers (This image is taken from reference (Aguilera et al., 2020))

3.1.4. KardiaMobile

KardiaMobile, developed by AliveCor, is a revolutionary wearable electrocardiogram (ECG) that uses AI to identify potentially life-threatening arrhythmias like atrial fibrillation. By allowing for earlier diagnosis and intervention, this cutting-edge technology can revolutionize cardiac care and reduce the prevalence of potentially fatal complications like stroke and heart failure (Goldenthal et al., 2019). Millions worldwide suffer from atrial fibrillation (AF), the most common form of irregular heart rhythm. Poor blood flow and an increased risk of blood clots result from the atria, the upper chambers of the heart, beating chaotically and irregularly, causing this condition. Stroke, heart failure, and even death can occur due to untreated atrial fibrillation (Benjamin et al., 2017). To overcome these obstacles, AliveCor designed KardiaMobile, a portable electrocardiogram (ECG) monitor that patients can use to monitor their home's heart rates. With the touch of a finger, the tiny smartphone accessory KardiaMobile records an electrocardiogram (ECG) from a single lead. Through a specialized app on the user's smartphone, recorded ECG data is transmitted to a computer, where artificial intelligence algorithms examine it for possible signs of atrial fibrillation. KardiaMobile's artificial intelligence (AI) algorithms have been trained and tested on massive amounts of ECG data from various patient populations. This ensures that the device can accurately detect a broad spectrum of abnormal heart rhythms. KardiaMobile's sensitivity of 93.6% and specificity of 99.1% in detecting AF in a clinical trial involving over 2,000 participants demonstrates the device's high accuracy and reliability in identifying this potentially life-threatening condition (Steinhubl et al., 2018). By giving people more control over their cardiac care, KardiaMobile improves patient engagement and self-management. KardiaMobile's ability to give patients real-time feedback on their heart rhythms can improve clinical outcomes

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and decrease healthcare costs by encouraging patients to take their medications as directed and adopt healthier lifestyle habits (Al-Alusi, Ding, McManus, & Lubitz, 2019).

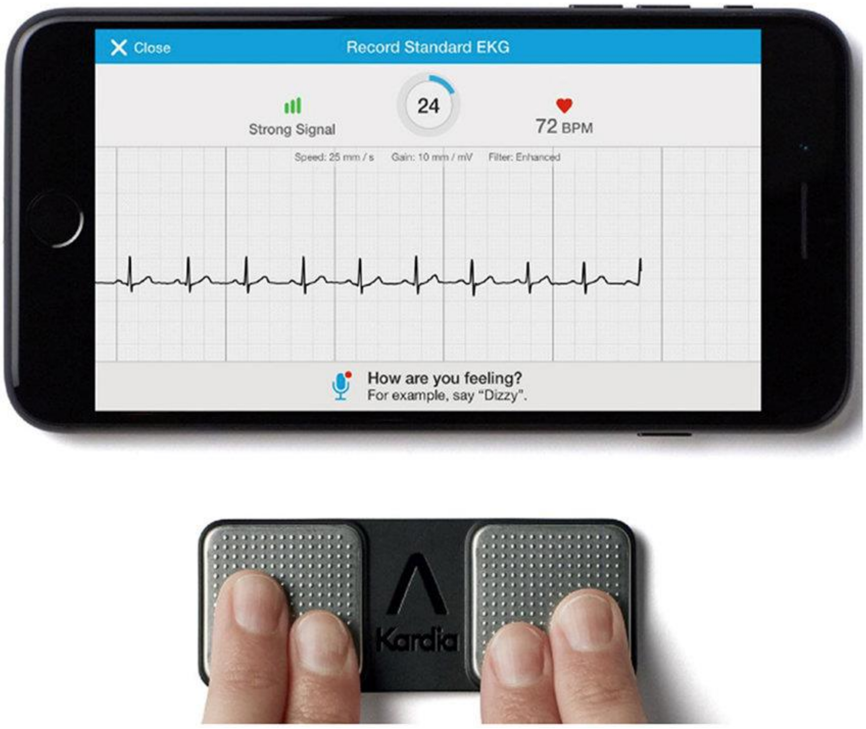

Figure 8. Single-lead handheld ECG AliveCor Kardia Mobile (This image is taken from reference (Veale et al., 2018))

4. Future of Biotechnology-Artificial Intelligence Nexus

In many aspects, the healthcare industry stands to benefit significantly from the integration of AI and biotechnology. This part, focusing on essential topics such as precision medicine, drug development, diagnostics, and ethics, will address the future paths and implications of this convergence in healthcare.

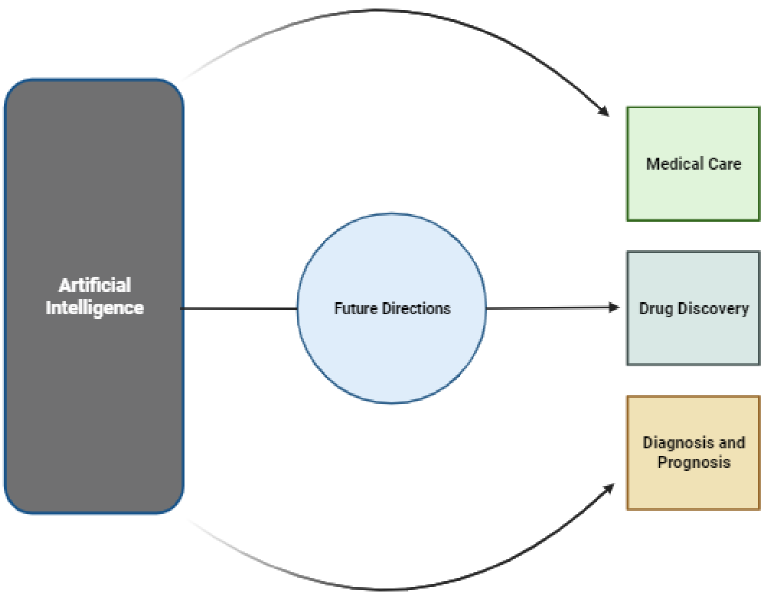

Figure 9. Future Directions of Biotechnology-Artificial Intelligence Nexus

4.1. Precise Medical Care

Improving precision medicine is a potentially fruitful area for the future integration of AI and biotechnology. Precision medicine aims to provide more individualized and efficient medical care by considering each patient's unique genetics, environmental circumstances, and way of life. By facilitating the study of large datasets, AI can help speed up the development of precision medicine by locating novel biomarkers and therapeutic targets (J. H. Chen & Asch, 2017).

4.2. Discovery of New Drugs

The integration of AI with biotechnology has the potential to revolutionize healthcare, particularly in medication development. Using machine learning algorithms, predicting drug-target interactions, finding novel compounds, and improving clinical trial candidates are all possible. This can speed up the introduction of innovative medicines for a wide range of ailments while decreasing the time and money required to bring them to market (Vamathevan et al., 2019).

4.3. Diagnosis and Prognosis

Integrating AI and biotechnology could significantly improve medical diagnosis and prognosis. By analyzing massive volumes of medical imaging data, AI-driven diagnostic systems might enhance the early identification and prediction of illnesses like cancer and neurological disorders. In order to improve patient outcomes, AI algorithms are increasingly being used to detect patterns and biomarkers often overlooked by human specialists (Topol, 2019).

5. Ethical Considerations and Challenges

The combination of AI and biotechnology has many practical applications in healthcare but presents severe ethical concerns and hurdles. The uneven distribution of AI-driven healthcare solutions can exacerbate health inequalities, raising serious ethical concerns. It is crucial to ensure that the advantages of modern technologies are dispersed fairly across all populations and prevent the growth of health disparities (Blasimme & Vayena, 2019). Furthermore, privacy and security issues develop when AI systems gather and analyze large volumes of personal and medical data. Maintaining patient confidence and avoiding inappropriate use of personal information necessitates strict adherence to best data storage and security practices. Finally, issues with validating and regulating AI-driven medical solutions arise from combining AI and biotechnology in healthcare. To fully realize these technologies' promise in healthcare, we must develop regulatory frameworks to evaluate their safety and efficacy while encouraging innovation (Holzinger, Weippl, Tjoa, & Kieseberg, 2021). In the future, academics, healthcare providers, politicians, and the general public will need to collaborate to fully realize AI and biotechnology's benefits in healthcare while meeting the obstacles they provide (Gerke, Yeung, & Cohen, 2020).

6. Conclusion

The Biotechnology-Artificial Intelligence Nexus represents the breakthrough convergence of two game-changing technologies that promise to change healthcare radically. The advantages and disadvantages of merging biotechnology and AI in healthcare and some advanced application case studies have been discussed in this review. Consistently collating these findings enables a vision of a future where these complimentary capabilities of

biotechnology and AI are harnessed to improve healthcare quality, efficiency, and access for everybody. This article discusses several advanced application case studies that employ AI to improve biotechnology. With the help of artificial intelligence, research and development in healthcare are being accelerated in all areas – drug discovery, proteomics, genetics, medical imaging, customized medicine, and other areas. The AI-driven biotechnology advances can lighten the economic burden of conventional research and development by streamlining processes and making healthcare systems more effective. Furthermore, analytics enabled by AI may illuminate complex biological processes, resulting in more knowledge-driven decisions and personalized treatment plans. These profits are likely to improve healthcare for patients, improve standards overall, and cater to the growing requirement for cost-effective services as the population of the world ages. Nevertheless, challenges arise when biotechnology and AI are merging in healthcare.

7. Future Directions & Improvements

For the Biotechnology-AI Nexus to reach its full potential, we must surmount its obstacles, including the requirement for interdisciplinary cooperation, data privacy and security issues, ethical dilemmas, regulatory compliance, and others. To address these concerns, researchers, healthcare providers, politicians, and industry stakeholders should collaborate to produce an environment that fosters responsible innovation and ensures equitable sharing of the gains. Worker dislocation is also a concern produced by the possibility of AI and automation changing the nature of the labor market. Re-skilling and up-skilling investment are necessary to ensure the healthcare staff possesses the competencies to adjust to technological changes as the Biotechnology-AI Nexus emerges.

Declarations

Source of Funding

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Conflict of Interest

This research was conducted in the absence of any commercial or financial relationships that could be construed as potential absence of conflict of interest.

Consent for Publication

The authors declare that they consented to the publication of this study.

Authors' Contribution

All authors of this review article, have worked collaboratively and contributed equally to every aspect of this study. From conceptualization to writing, review, and finalization, each author has played an equal and vital role in the development of this manuscript. The collaborative effort and shared responsibilities among all authors have

ensured a balanced and comprehensive approach to this research. All authors have collectively read and endorsed the final version of the manuscript, highlighting their equal and substantial contributions to the research and publication process.

References

Abonamah, A.A., Tariq, M.U., & Shilbayeh, S. (2021). On the Commoditization of Artificial Intelligence. Frontiers in Psychology, 12: 696346. https://doi.org/10.3389/fpsyg.2021.696346.

Aguilera, S., Quintana, L., Khan, T., Garcia, R., Shoman, H., Caddell, L., & Dempsey, R. (2020). Global health, global surgery and mass casualties: II. Mass casualty centre resources, equipment and implementation. BMJ Global Health, 5(1): e001945. https://doi.org/10.1136/bmjgh-2019-001945.

Ahmed, M.N., Toor, A.S., O'Neil, K., & Friedland, D. (2017). Cognitive computing and the future of health care cognitive computing and the future of healthcare: the cognitive power of IBM Watson has the potential to transform global personalized medicine. IEEE Pulse, 8(3): 4–9. https:doi.org/10.1109/MPUL.2017.2678098.

Al-Alusi, M.A., Ding, E., McManus, D.D., & Lubitz, S.A. (2019). Wearing your heart on your sleeve: the future of cardiac rhythm monitoring. Current Cardiology Reports, 21: 1–11. https://doi.org/10.1007/s11886-019-1223-8.

Arora, S., Kumar, A., Ogita, S., & Yau, Y.Y. (2022). Biotechnological Innovations for Environmental Bioremediation. Springer Nature.

Asia, A.O., Zhu, C.Z., Althubiti, S.A., Al-Alimi, D., Xiao, Y.L., Ouyang, P.B., & Al-Qaness, M.A. (2022). Detection of diabetic retinopathy in retinal fundus images using CNN classification models. Electronics, 11(17): 2740. https://doi.org/10.3390/electronics11172740.

Benjamin, E.J., Blaha, M.J., Chiuve, S.E., Cushman, M., Das, S.R., Deo, R., & Gillespie, C. (2017). Heart disease and stroke statistics—2017 update: a report from the American Heart Association. Circulation, 135(10): e146–e603. https://doi.org/10.1161/CIR.0000000000000485.

Blasimme, A., & Vayena, E. (2019). The ethics of AI in biomedical research, patient care and public health. Patient Care and Public Health (April 9, 2019). Oxford Handbook of Ethics of Artificial Intelligence, Forthcoming. https://doi.org/10.1093/oxfordhb/9780190067397.013.45.

Chen, C., Yaari, Z., Apfelbaum, E., Grodzinski, P., Shamay, Y., & Heller, D.A. (2022). Merging data curation and machine learning to improve nanomedicines. Advanced Drug Delivery Reviews, 114172. https://doi.org/10.1016/j.addr.2022.114172.

Chen, J.H., & Asch, S.M. (2017). Machine learning and prediction in medicine—beyond the peak of inflated expectations. The New England Journal of Medicine, 376(26): 2507. https://doi.org/10.1056/NEJMp1702071.

Dash, S., Shakyawar, S.K., Sharma, M., & Kaushik, S. (2019). Big data in healthcare: management, analysis and future prospects. Journal of Big Data, 6(1): 1–25. https://doi.org/10.1186/s40537-019-0217-0.

Gerke, S., Yeung, S., & Cohen, I.G. (2020). Ethical and legal aspects of ambient intelligence in hospitals. Jama, 323(7): 601–602. https://doi.org/10.1001/jama.2019.21699.

Goldenthal, I.L., Sciacca, R.R., Riga, T., Bakken, S., Baumeister, M., Biviano, A.B., & Whang, W. (2019). Recurrent atrial fibrillation/flutter detection after ablation or cardioversion using the AliveCor KardiaMobile device: iHEART results. Journal of Cardiovascular Electrophysiology, 30(11): 2220–2228. https://doi.org/10.1111/jce.14160.

Gorjian, S., Sharon, H., Ebadi, H., Kant, K., Scavo, F.B., & Tina, G.M. (2021). Recent technical advancements, economics and environmental impacts of floating photovoltaic solar energy conversion systems. Journal of Cleaner Production, 278: 124285. https://doi.org/10.1016/j.jclepro.2020.124285.

Gulshan, V., Peng, L., Coram, M., Stumpe, M.C., Wu, D., Narayanaswamy, A., & Cuadros, J. (2016). Development and validation of a deep learning algorithm for detection of diabetic retinopathy in retinal fundus photographs. Jama, 316(22): 2402–2410. https://doi.org/10.1001/jama.2016.17216.

Haidari, L.A., Brown, S.T., Ferguson, M., Bancroft, E., Spiker, M., Wilcox, A., & Lee, B.Y. (2016). The economic and operational value of using drones to transport vaccines. Vaccine, 34(34): 4062–4067. https://doi.org/10.1016/j.vaccine.2016.06.022.

Hassanzadeh, P., Atyabi, F., & Dinarvand, R. (2019). The significance of artificial intelligence in drug delivery system design. Advanced Drug Delivery Reviews, 151: 169–190. https://doi.org/10.1016/j.addr.2019.05.001.

Hesham, A.E.L., Kaur, T., Devi, R., Kour, D., Prasad, S., Yadav, N., & Yadav, A.N. (2021). Current trends in microbial biotechnology for agricultural sustainability: conclusion and future challenges. Current Trends in Microbial Biotechnology for Sustainable Agriculture, Pages 555–572. Doi: 10.1007/978-981-15-6949-4_22.

Holzinger, A., Keiblinger, K., Holub, P., Zatloukal, K., & Müller, H. (2023). AI for life: Trends in artificial intelligence for biotechnology. New Biotechnology, 74: 16–24.

Holzinger, A., Weippl, E., Tjoa, A.M., & Kieseberg, P. (2021). Digital transformation for sustainable development goals (sdgs)-a security, safety and privacy perspective on AI. Paper presented at the Machine Learning and Knowledge Extraction: 5th IFIP TC 5, TC 12, WG 8.4, WG 8.9, WG 12.9 International Cross-Domain Conference, CD-MAKE 2021, Virtual Event, August 17–20, 2021, Proceedings 5. https://doi.org/10.1016/j.nbt.2023.02.001.

Johnson, K.B., Wei, W.Q., Weeraratne, D., Frisse, M.E., Misulis, K., Rhee, K., & Snowdon, J.L. (2021). Precision medicine, AI, and the future of personalized health care. Clinical and Translational Science, 14(1): 86–93. https://doi.org/10.1111/cts.12884.

Kashkha, A. (2023). The future of artificial intelligence in biotechnology: Current challenges and outcomes. Medium. https://medium.com/@kashkha1786/the-future-of-artificial-intelligence-in-biotechnology-current-challenges-and-outcomes-bce879efe061.

Kaswan, K.S., Dhatterwal, J.S., Kumar, N., & Lal, S. (2023). Artificial Intelligence for Financial Services. In Contemporary Studies of Risks in Emerging Technology, Part A., Pages 71–92, Emerald Publishing Limited. https://doi.org/10.1108/978-1-80455-562-020231006.

Kim, B. (2020). Moving forward with digital disruption: What big data, IoT, synthetic biology, AI, blockchain, and platform businesses mean to libraries. https://doi.org/10.5860/ltr.56n2.

Kropp, M., Golubnitschaja, O., Mazurakova, A., Koklesova, L., Sargheini, N., Vo, T.T.K.S., & Polivka, J. (2023). Diabetic retinopathy as the leading cause of blindness and early predictor of cascading complications—Risks and mitigation. EPMA Journal, 14(1): 21–42. https://doi.org/10.1007/s13167-023-00314-8.

Kuddus, K. (2022). Artificial Intelligence in Language Learning: Practices and Prospects. Advanced Analytics and Deep Learning Models, Pages 1–17. https://doi.org/10.1002/9781119792437.ch1.

Lockhart, A., While, A., Marvin, S., Kovacic, M., Odendaal, N., & Alexander, C. (2021). Making space for drones: The contested reregulation of airspace in Tanzania and Rwanda. Transactions of the Institute of British Geographers, 46(4): 850–865. https://doi.org/10.1111/tran.12448.

Lysunets, T. (n.d.). Biotechnology» and «Technosphere Safety».

Moor, M., Banerjee, O., Abad, Z.S.H., Krumholz, H.M., Leskovec, J., Topol, E.J., & Rajpurkar, P. (2023). Foundation models for generalist medical artificial intelligence. Nature, 616(7956): 259–265. https://doi.org/10.1038/s41586-023-05881-4.

Padhy, I., Mahapatra, A., Saraswat, R., & Song, J. (2020). Role of biotechnology in pharmaceutical research: A comprehensive review. Pharm Sci., 7: 472–486.

Prado, D.A., Acosta-Acero, M., & Maldonado, R.S. (2020). Gene therapy beyond luxturna: a new horizon of the treatment for inherited retinal disease. Current Opinion in Ophthalmology, 31(3): 147–154. https://doi.org/10.1097/ICU.0000000000000660.

Raman, R., Srinivasan, S., Virmani, S., Sivaprasad, S., Rao, C., & Rajalakshmi, R. (2019). Fundus photograph-based deep learning algorithms in detecting diabetic retinopathy. Eye, 33(1): 97–109. https://doi.org/10.1038/s41433-018-0269-y.

Rebelo, N., Sanders, L., Li, K., & Chow, J.C. (2022). Learning the Treatment Process in Radiotherapy Using an Artificial Intelligence–Assisted Chatbot: Development Study. JMIR Formative Research, 6(12): e39443. https://doi.org/10.2196/39443.

Rodrigues, A.G. (2020). Global players: resources and profits. In New and Future Developments in Microbial Biotechnology and Bioengineering, Pages 187–208, Elsevier. doi: 10.1016/B978-0-444-64301-8.00009-3.

Schaeffer, D.M., & Olson, P.C. (2019). Drones: 4DT Applications in US Industry and Public Policy. Journal of Strategic Innovation and Sustainability, 14(3): 93–97.

Shava, E. (2022). Survival of african governments in the fourth industrial revolution. Africa and the Fourth Industrial Revolution: Curse or Cure?, Pages 125–144.

Singh, P., Singh, N., Singh, K.K., & Singh, A. (2021). Diagnosing of disease using machine learning. In Machine learning and the internet of medical things in healthcare, Pages 89–111, Elsevier. https://doi.org/10.1016/B978-0-12-821229-5.00003-3.

Somashekhar, S., Sepúlveda, M.J., Puglielli, S., Norden, A., Shortliffe, E.H., Kumar, C.R., & Rhee, K. (2018). Watson for Oncology and breast cancer treatment recommendations: agreement with an expert multidisciplinary tumor board. Annals of Oncology, 29(2): 418–423. https://doi.org/10.1093/annonc/mdx781.

Steinhubl, S.R., Waalen, J., Edwards, A.M., Ariniello, L.M., Mehta, R.R., Ebner, G.S., & Sarich, T. (2018). Effect of a home-based wearable continuous ECG monitoring patch on detection of undiagnosed atrial fibrillation: the mSToPS randomized clinical trial. Jama, 320(2): 146–155. http://doi.org/10.1001/jama.2018.8102.

Tarr, A.A., Perera, A.G., Chahl, J., Chell, C., Ogunwa, T., & Paynter, K. (2021). Drones—healthcare, humanitarian efforts and recreational use. In Drone Law and Policy, Pages 35–54, Routledge.

Ting, D.S.W., Pasquale, L.R., Peng, L., Campbell, J.P., Lee, A.Y., Raman, R., & Wong, T.Y. (2019). Artificial intelligence and deep learning in ophthalmology. British Journal of Ophthalmology, 103(2): 167–175. https://doi.org/10.1136/bjophthalmol-2018-313173.

Topol, E.J. (2019). High-performance medicine: the convergence of human and artificial intelligence. Nature Medicine, 25(1): 44–56. https://doi.org/10.1038/s41591-018-0300-7.

Truong, Y., & Papagiannidis, S. (2022). Artificial intelligence as an enabler for innovation: A review and future research agenda. Pages 121852, Elsevier. https://doi.org/10.1016/j.techfore.2022.121852.

Vamathevan, J., Clark, D., Czodrowski, P., Dunham, I., Ferran, E., Lee, G., & Spitzer, M. (2019). Applications of machine learning in drug discovery and development. Nature Reviews Drug Discovery, 18(6): 463–477. https://doi.org/10.1038/s41573-019-0024-5.

Veale, E.L., Stewart, A.J., Mathie, A., Lall, S.K., Rees-Roberts, M., Savickas, V., & Corlett, S.A. (2018). Pharmacists detecting atrial fibrillation (PDAF) in primary care during the influenza vaccination season: a multisite, cross-sectional screening protocol. BMJ Open, 8(3): e021121. doi: 10.1136/bmjopen-2017-021121.

Velidandi, A., Gandam, P.K., Chinta, M.L., Konakanchi, S., Bhavanam, A.R., Baadhe, R.R., & Gupta, V.K. (2023). State-of-the-art and future directions of machine learning for biomass characterization and for sustainable biorefinery. Journal of Energy Chemistry. https://doi.org/10.1016/j.jechem.2023.02.020.

Vijaya, G. (2022). Deep Learning-Based Computer-Aided Diagnosis System. In Application of Deep Learning Methods in Healthcare and Medical Science, Pages 23–48, Apple Academic Press.

Waden, J. (2022). Artificial intelligence and its role in the development of personalized medicine and drug control: artificial intelligence and its role in the development of personalized medicine and drug control. Wasit Journal of Computer and Mathematics Sciences, 1(4): 194–206. https://doi.org/10.31185/wjcm.85.

Wan, S., Gu, Z., & Ni, Q. (2020). Cognitive computing and wireless communications on the edge for healthcare service robots. Computer Communications, 149: 99–106. https://doi.org/10.1016/j.comcom.2019.10.012.

Yathiraju, N., & Mohapatra, A. (2023). The Implications of IoT in the Modern Healthcare Industry post COVID-19. https://doi.org/10.3389/fpsyg.2021.696346.